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TERRAIN VISUALIZATION BY SOLDIERS (U)

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Reading a military map is an important, but often difficult, soldiering task. Map reading requires not only reading and mathematical skills, but also complex problem-solving and perceptual skills. Soldiers must be able to read map symbols and special map vocabulary, calculate and estimate distance and direction, be aware of geographic orientation, and understand the meaning and interpretation of contour lines. Contour lines are mechanisms by which military maps represent land formations and relief. Soldiers must be able to quickly use the two-dimensional contour lines to visualize the three-dimensional terrain over which they must navigate. Soldiers must also be able to translate the spatial information in the environment to a two-dimensional contour line pattern so that they can isolate a current location.

The ability to visualize the three-dimensional terrain from its two-dimensional contour line representation is the most complex cognitive skill required of the map reader. This skill, called terrain visualization, is also the most difficult map reading skill to train. Map users report difficulty visualizing the terrain from contour lines (1) and trainers generally agree that there are large individual differences in this ability.

All enlisted soldiers receive limited map reading instruction during Basic Training. Some soldiers receive additional training, also limited in time, during Advanced Individual Training. For many soldiers, however, map reading skills must be developed on the job. Where formal map reading training exists, much of the classroom time must be spent teaching mathematical techniques and the special symbols required for map reading. Little time is left for developing and practicing terrain visualization skills.

Current techniques for training terrain visualization vary, and include having soldiers read sections of map reading manuals, presenting slides of contour maps and associated terrains, or providing field

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experience in which the trainer walks with a group of students and indicates land formations and associated contour line patterns on a map. Trainers and commanders in the field have stated that along with apparent individual differences in spatial abilities, extended experience with a variety of terrains and contour line representations is a major factor in the development of terrain visualization skills (2). Thus, techniques which can broaden and increase terrain visualization experience in a short time period could lead to improved map reading training and performance.

One technique with high potential for improving terrain visualization skills is the use of computer graphics. Recent developments in computer technology can provide a means to simulate field experience and enable soldiers to practice terrain visualization with a large variety of terrains. Computers can generate contour line maps and present their three-dimensional representations quickly and realistically on a graphics display. For example, computer-based terrain visualization techniques used in this research allow a soldier to view a simplified contour map in the upper half of a computer display, place and rotate a cursor at any location on the map, and subsequently view simulated three-dimensional terrain corresponding to the cursor's position and direction. In effect, the soldier sees a graphic representation of what he or she would see if actually standing at that map location looking in that particular direction. Figure 1 shows an example of one simplified map, cursor position and direction, and associated terrain visualization. Techniques such as these are exciting and offer many potential applications within the Army.

As with any other technology, however, simply putting costly computer graphics systems into the classroom to assist in training will not necessarily lead to improved terrain visualization performance. Instructional developers and trainers must know how to effectively use the technology as a training tool.

The purpose of this research was to explore the application of computer graphics to terrain visualization problems using two training techniques. Individual differences in spatial abilities were also considered because researchers have shown that although spatial ability is generally not related to overall intelligence level, it plays a critical role in the performance of spatially related tasks (3).

Enlisted soldiers with limited terrain visualization training were first tested on their spatial ability and divided into three spatial ability groups, either high, medium or low. All soldiers were given about one hour of computer-assisted instruction in map fundamentals required for terrain visualization. Half the soldiers in each spatial group then either actively (that is, made their own decisions about cursor position and direction) or passively (that is, the computer randomly made the decisions) practiced with
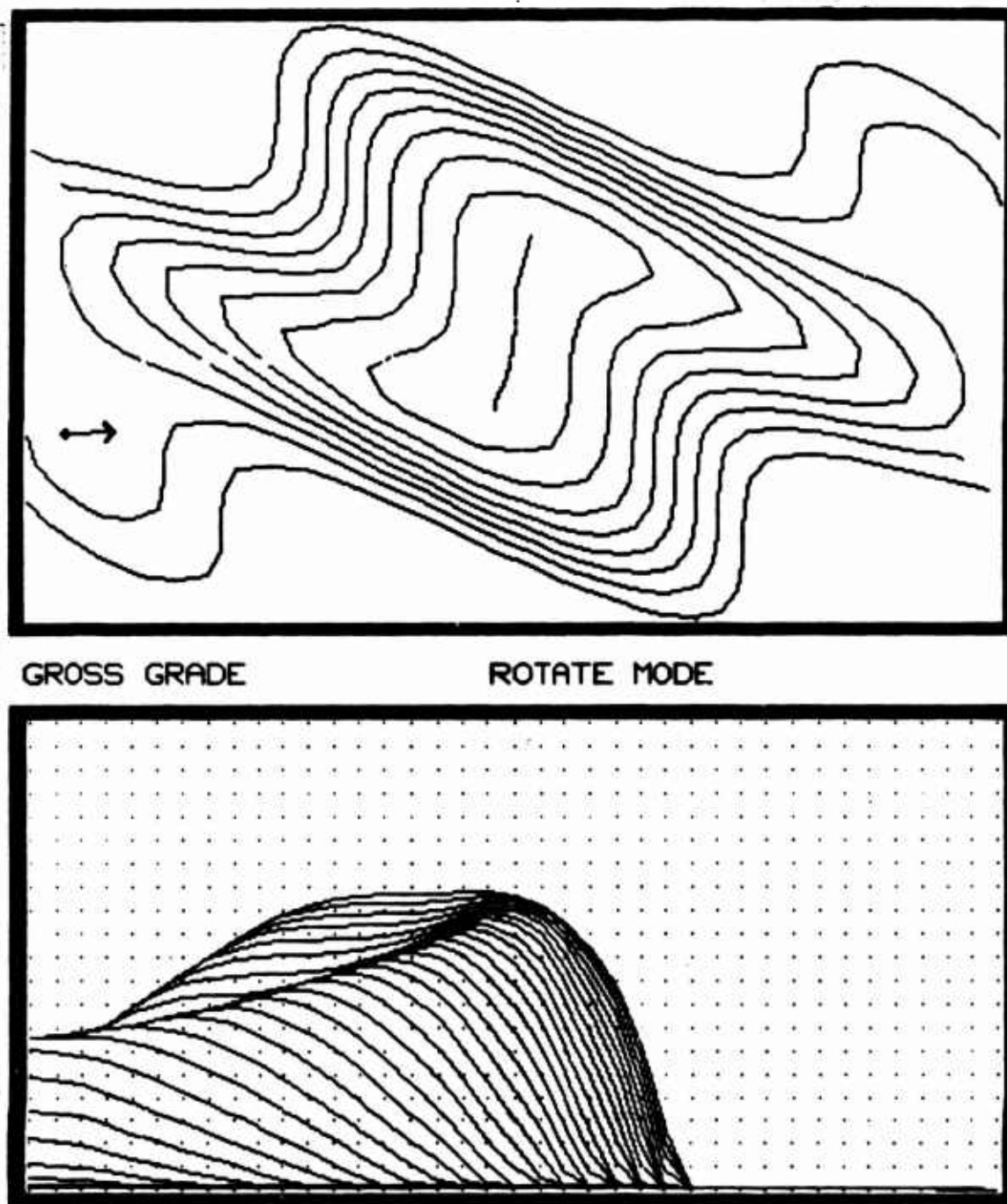
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GROSS GRADE   ROTATE MODE

Figure 1.   Example of computer display of contour map and associated
terrain visualization.

computer-based terrain visualization techniques. Finally, all soldiers were tested on an ARI developed paper-and-pencil terrain visualization test.

METHOD

Subjects and Design

Sixty enlisted soldiers (6 females, 54 males) stationed at Ft Belvoir, VA participated in the research. All soldiers had limited training and/or experience in map reading and terrain visualization. Their ages ranged from 17 to 33 with mean age at 21.9 years. Soldiers were tested on spatial subtests from the Kit of Factor-Referenced Cognitive Tests (4) prior to the experiment. Soldiers were divided into three spatial ability groups (high, medium, or low) based on their spatial scores. Soldiers in each spatial group were then randomly assigned to one of two terrain visualization training conditions, either active or passive. Thus, the design was a 2-by-3 factorial design consisting of six groups with 10 soldiers per group.

Computer-Based Training Materials

With US Army Research Institute for the Behavioral and Social Sciences (ARI) assistance, the University of Illinois ROTC unit developed a series of computer-based lessons for training ROTC students in map reading.[1] The lessons were developed using the University of Illinois PLATO Computer-Based Education System. More information about this system can be found in Reference 5. The authors modified two of these lessons for use in this research. Elevation, Relief and Terrain Features covers topics required for terrain visualization, such as, elevation, relief, contour lines, slope, and terrain features. Interpretation of Contour Lines provides practice in terrain visualization as described earlier. In addition to providing three dimensional views as shown in Figure 1, ground profiles can be generated in the bottom half of the screen by moving the cursor across the map in the upper half of the screen. Rather than drawing the three-dimensional views from digitized map data bases as many other systems do, this lesson approximates the views by calculating bivariate normal probability density functions.

Training Conditions

Two versions, active and passive, of the Interpretation of Contour Lines lessons were developed for terrain visualization practice. The

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general approach was to have soldiers view one of four simplified contour maps and subsequently see the ground profile or land formation associated with a specific place on the map. All soldiers saw the same contour maps and were permitted to view the terrain of two of these maps in ground profile for ten minutes per map. The remaining two maps provided three-dimensional terrain visualization practice for twenty minutes per map.

Active Practice. Under the active practice condition, soldiers were freely allowed to explore each contour map, selecting the ground profiles and three dimensional visualizations they wished to see. Soldiers made all decisions about cursor position and direction. Soldiers could view as many displays per map as they wished until the time limit expired.

Passive Practice. Under the passive practice condition, the soldiers' role was to watch displays randomly chosen from positions at the edge of the map frame boundaries directed toward the map center. In all other respects the training conditions were identical: maps were identical, time of viewing each map was identical, and soldiers could view as many displays per map as they wished until the time limit expired.

Terrain Visualization Test Materials

Three subtests from ARI's Relief Assessment Test (6) were used to test soldiers' post-training terrain visualization performance. This paper-and-pencil test was originally developed to assist cartographers in assessing the effects of map design changes. The three selected subtests, each with twelve test items, were:

(1) Landform Identification. The user identifies landforms beneath the tips of arrows overprinted on map segments. The landforms to be identified (hill, valley, spur, depression, and saddle) are illustrated in pencil sketches.

(2) Ridge Valley Identification. The user determines whether lines overprinted on map segments run along: (a) a uniform up slope, (b) a uniform down slope, (c) a convex up slope, or (d) a concave down slope.

(3) Terrain Visualization. The user selects the scene one would see if standing at an arrowtip overprinted on a map segment, looking in the direction shown by the arrow.

Procedure

Spatial Pretest. Soldiers were pretested on the subtests of the spatial test (4) in groups of about seven soldiers prior to training. Administration of the test required one hour. After soldiers completed the tests, arrangements were made for them to return to complete the experiment.

The sample mean and standard deviation of all 60 soldiers' scores on the spatial test were calculated and spatial ability groups were determined from these measures. The high spatial ability group had scores greater than one-half standard deviation above the mean (52-116). Medium ability soldiers had scores greater than one-half standard deviation below the mean but no more than one-half standard deviation above the mean (24-51). Low spatial ability group members had scores less than one-half standard deviation below the mean (0-23). Half the soldiers in each spatial group were randomly assigned to one of the two training conditions, either active or passive.

Training. In groups of about seven, soldiers received a general orientation to the experiment, and completed a biographic information survey about their previous map reading experiences or training, subjective opinion of their perceived ability to read maps and explore unfamiliar areas, as well as information about age, rank, and time in service. Soldiers were all assigned a code number so that the information supplied by the soldiers as well as all experimental scores would be anonymous.

Soldiers were then seated at PLATO terminals in the Education Center, Ft Belvoir, VA, and signed onto the computer system. All lessons and instructions were delivered on-line via a computerized routing sequence. Soldiers were presented with material in a sequenced order with options for reviewing the instructions only. After a lesson was completed, the soldiers were routed directly to the next appropriate lesson.

All soldiers worked on the self-paced Elevation, Relief, and Terrain Features lesson for about one hour. Soldiers then practiced terrain visualization with the version of Interpretation of Contour Lines appropriate to their assigned group, either active or passive, for exactly one hour.

Terrain Visualization Test. After completing all training, all soldiers answered the 36 items from the subtest of the ARI Relief Assessment Test. The test was self-paced and all soldiers completed the test. Testing time ranged from 30 to 150 minutes. Scores on the test, corrected for guessing, served as the measure of soldiers' terrain visualization performance level after training.

RESULTS

Soldiers' adjusted scores on the subtests of Relief Assessment Test are shown in Table 1 as a function of spatial ability and training condition. The data were analyzed using a two-way between-subjects analysis of variance.

Because the overall analysis of variance showed a significant interaction between spatial ability and training condition, F (2,54) = 4.42, $p < .02$, tests of simple effects and orthogonal comparisons were performed.

Table 1. Soldiers adjusted scores on the ARI Relief Assessment Subtest as a function of training condition and spatial ability level.[a]

| | Training Condition | |
Spatial Ability	Active	Passive
High	17.895	9.508
Medium	5.031	5.648
Low	1.728	1.610

Note. Maximum Score = 36

[a] n = 10 for each cell.

High spatial ability soldiers had higher adjusted scores than medium or low spatial ability soldiers under the active, F (1,54) = 49.63, $p < .001$, and the passive, F (1,54) = 8.14, $p < .001$, terrain visualization training conditions. Although adjusted scores were higher for medium spatial ability soldiers than for low spatial ability soldiers, the differences were not significant under the active, F (1,54) = 1.93 and the passive, F (1,54) = 2.88, training conditions.

High spatial ability soldiers who actively practiced terrain visualization during training had higher adjusted scores than soldiers who passively practiced, F (1,54) = 12.43, $p < .001$. Indeed, for these soldiers active practice resulted in performance almost twice as high as passive practice. Type of practice during terrain visualization training clearly had no effect for medium F (1,54) = .07, or low spatial ability soldiers, F (1,54) = .001.

DISCUSSION

In this research we found effects of spatial abilities and computer-based graphic training techniques on terrain visualization performance. High spatial ability soldiers were better able to perform terrain visualization tasks after two hours of computer-based training and practice than were lower spatial ability soldiers. When high spatial ability soldiers were allowed to actively select the three-dimensional views and ground

profiles to be generated by the computer, their performance on terrain visualization tasks nearly doubled. Active practice, however, did not improve the performance of the medium and low spatial ability soldiers. The terrain visualization performance of these soldiers was identical under both training conditions.

One reasonable explanation for these results is as follows: the active practice training group differed from the passive group in that the active group was able to choose the views that they wanted to see rather than simply being presented with random views. This active choice process allowed an individual to impose structure in the learning situation in the absence of any pre-existing structure, but only if the individual had sufficient spatial abilities to select information-rich views. It may be that what was critical to learning in the active terrain visualization practice was not simply being able to choose, but rather the structure itself that resulted from the choosing. For soldiers in the active practice group having high spatial abilities allowed choices that resulted in a reasonably structured learning situation. Because they lacked the same level of visual skills, however, our lower spatial ability soldiers could not make good choices of views to see, so that their choices were essentially random. Furthermore, our high spatial soldiers in the passive condition found it difficult to impose any structure on the learning situation because they only saw random views.

This reasoning suggests an instructional technique that could improve the efficiency of computer graphic terrain visualization practice for all spatial ability level soldiers: improve the level of structure inherent to the practice itself. For example, the computer could initially guide soldiers in selecting views, showing them how small changes in cursor position or direction change the terrain display. Using more sophisticated techniques, the computer could individualize the amount and type of structure for soldiers of different spatial ability levels.

It may be, however, that entirely different techniques, as yet unknown, are required to train lower spatial ability soldiers in terrain visualization skills. Lower spatial ability soldiers also may need more time than higher spatial ability soldiers to actively practice terrain visualization skills. Finally, it is possible that lower spatial ability soldiers may never perform as well as high spatial ability soldiers at terrain visualization, no matter how sophisticated the training technique or the technology used to deliver the training.

This research also serves as an example of the need to consider characteristics of trainees and the training methods to be used when investing in a new technology to be used for training. On the surface, using a computer display which allows a soldier to move around on a contour map and see changes in terrain as one travels appears to be a better training

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technique than showing soldiers points on a contour map with slides (or computer simulations) of associated terrains. Our research has shown that it is, but only for soldiers with high spatial abilities. This does not mean that computer graphics technology is not a viable technology for training terrain visualization to soldiers of lower spatial ability. It means that before optimal use of the technology can be made, we need a better understanding of individual differences in spatial and terrain visualization processes, and development of instructional techniques appropriate to meet these individual differences.

REFERENCES

1. Skop, J. Investigation of user requirements pertinent to relief portrayal. Army Map Service, Corps of Engineers. Final Report, 1958.

2. Army's FORMIDABLE Conference, Ft Benning, GA, February 1978.

3. McGee, M.G. Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences. Psychological Bulletin, 1979, 86, 889-918.

4. Ekstrom, R.B., French, J.W., Harman, H.H., & Dermen, D. Manual for Kit of factor-referenced cognitive tests. Princeton, N.J.: Educational Testing Service, 1976.

5. Smith, S.G., & Sherwood, B.A. Educational uses of the PLATO computer system. Science, 1976, 192, 344-352.

6. Potash, L.M., Farrell, J.P., Jeffery, T. A technique for assessing map relief legibility. The Cartographic Journal, 1978, 15, 28-35.